

Clarkson University Intelligent Cars IV

System Requirements Specifications Document

Revision A - September 6, 2017

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Table of Contents

1. **Scope**
   1. **Identification**
   2. **Document Overview**
   3. **System Overview**
2. **Definitions**
3. **Requirements/Attributes**
   1. **Generic Requirements**
   2. **System Constraints**
   3. **Functional Requirements**
   4. **Qualitative Attributes**
   5. **Quantitative Attributes**
   6. **Options**
4. **Verification**
5. **Supporting Documents**
   1. **Product Concept**
   2. **Team Contract**
   3. **Test Plan**
   4. **List of Deliverables**
6. **References**
7. **Scope**
   1. **Identification**

This document serves as the System Requirements Specifications Document for the Clarkson University Intelligent Cars IV project as part of the University’s Computer Engineering Senior Lab class. This document’s reference number is KVM-D100001.

* 1. **Standards**
     1. This specification follows IEEE Standards 830 and 1233.
     2. The two cars’ design process shall follow the methodologies of both Design for Assembly and Design for Manufacturability in order to create a product which is both simplistic and highly modifiable in design.
     3. The cars shall be built by this team (KVM) while strictly adhering to the Team Code of Ethics as well as each member’s individual Code of Ethics.
  2. **Document Overview**
     1. **Section 2**

Section 2 is comprised of a list of definitions which are critical to the reader’s understanding of the document and of the system/project as a whole.

* + 1. **Section 3**

Section 3 is a list of references available to the reader which offer more detailed explanations of the hardware and software used by this system in its operational functions.

* + 1. **Section 4**

Section 4 details the system requirements in full.

Section 4.1: generic system requirements.

Section 4.2: system constraints.

Section 4.3: functional requirements.

Section 4.4: qualitative attributes of the system.

Section 4.5: quantitative attributes of the system.

Section 4.6: optional attributes of the system which have the possibility of being added in the future.

* + 1. **Section 5**

Section 5 lists the verification methods proposed for verifying that the outlined requirements of the document have been fulfilled.

* + 1. **Section 6**

Section 6 outlines the supporting documents related to this document.

* + 1. **Section 7**

Section 7 contains the appendices of the document.

* 1. **System Overview**

The system under development which is referenced by this document (Clarkson University Intelligent Cars IV) is a project undertaken by the participating members of the Senior Lab class of the Computer Engineering program. The project task is to develop, design, build, and test a functional intelligent small-scale vehicle which has the ability to perform several different modes of operation. The underlying basis of each of these modes is a small track which the car must navigate in some fashion depending on the mode. These modes are outlined in the Product Concept in the Supporting Documents section of this document.

The vehicle itself is to be comprised of a remote control car chassis with attached dual-drive DC motors to power the wheels. The vehicle will also have a servo steering mechanism, a CMUcam5 Pixy camera to recognize directional markers on the track, a line scanner to recognize the track itself, and a pan-tilt mechanism to alter the viewpoint of the Pixy camera. There will be two separate boards which will each have independently the task of serving as the central processing unit of the vehicle itself at different times (each capable of performing the same tasks and fulfilling the outlined requirements). These boards will have the ability to be swapped with minimal modification to function properly. Each board shall be able to direct the car in every task outlined below and will be programmed as such.

1. **Definitions**
   1. Car: either one of the vehicles in production which carries either of the main controllers
   2. Track: a 2.54cm wide black curve on a white background
   3. Front: When used in respect to the car, it is a designated side of the car
   4. Forward: When used in respect to the car, it is a singular directional vector based on a single designated point and extends away from the car perpendicular to the front
   5. Vision sensor: the CMUcam5 Pixy camera
   6. Directional marker: a length of PVC, standing on one of its non-rounded sides, with two pieces of distinct colored duct tape wrapped around the side furthest from the ground
   7. Placed within: When used in respect to the car’s position, it means that the car position, in relation to the object it is being placed near, is measured from the part of the external object nearest to the car to the part of the car nearest to the external object
   8. Turn around: When used in respect to the movement of the car, it means that the car shall perform a maneuver such that be able to travel forward in a direction 180 degrees from the direction it was traveling prior
   9. Stop: When used in respect to the movement of the car, it means that the car shall cease movement
   10. Continue: When used in respect to the movement of the car, it means that the car shall continue moving forward along the track
   11. Main controller: A reference to either one of the FRDM-K64F board or the Zynq-based board
   12. Signature X: a directional marker in which the two pieces of colored duct tape are different colors in order to indicate a unique combinational signature, ‘X’
   13. Power up: Describes the event in which the car is turned on
   14. Starting line: a point on the track that has a another perpendicular line on each side of the track
   15. Around the track: When used in respect to the car’s movement, this means that the car will traverse the track while either keeping the track between the wheels or keeping at least one two wheels on the track
   16. Separation between cars: The shortest linear distance between the two measured cars
   17. Other computer: A computer that is not the main controller
   18. External interaction: Interaction between the main controller or any other part of the car with any other computer, human, or car
2. **Requirements & Attributes**
   1. **Generic Requirements**
      1. The cars shall be built using only components given by the customer and additional components not totaling in value over $150.
      2. The cars shall be built to an aesthetically appealing standard dictated by the team. This means that the team will actively attempt to neatly wire all components as well as make cosmetic changes that offer no functional benefit, but will make the car visually unique, with negligible impact on the budget.
   2. **System Constraints**
      1. The cars shall utilize non-simultaneously an NXP FRDM-K64F board, and a Zynq-based board, in unison with the other components, to control the overall functionality of the car and guide the car in its desired operation.
      2. The cars must use the following parts:
         1. A 4-wheel model car chassis with dual drive DC motors on the rear and front steerable wheels.
         2. A servo steering motor.
         3. A rechargeable battery.
         4. Zynq Based board (Zedboard or Zybo) and a NXP FRDM-K64F board, one for each car.
         5. H-bridge motor drivers and voltage regulators.
         6. A Line Scan Camera with TAOS linear sensor array (1 x 128-pixel image).
         7. A CMUcam5 Pixy vision sensor camera that can process and update detected objects every 20 milliseconds.
         8. A camera mount with two servo based pan-tilt mechanism that can be controlled by the microcontroller.
      3. The Zynq-based board shall be programmed using Xilinx Vivado 2017.
      4. The Freedom board shall be programmed using any available IDE which is compatible, with the exception of mbed and Keil.
      5. The cost of the cars, aside from given hardware, shall not total over $150.
   3. **Functional Requirements**
      1. **Overview**
         1. The car shall sense if it is on the track.
         2. The car shall be capable of moving forward along the track.
         3. The car shall be capable of locating the track when placed within 60.96cm of the track, when in discovery mode.
         4. The car shall avoid collisions with other cars on the track, when in collision avoidance mode.
         5. The car shall use the vision sensor to detect the directional markers.
         6. The vision sensor shall provide information to the car based on the directional markers.
         7. The car shall be able to use the vision sensor information to decide whether to turn left, turn right, turn around, stop, or continue at each intersection.
      2. **General Car and Controller**
         1. The car shall be able to function non-simultaneously with both a Zynq Based (Zedboard or Zybo) board and a NXP FRDM-K64F board as the main controller.
         2. The visual sensor mount shall be able to pan and tilt with a controlling mechanism.
         3. The visual sensor shall be able to define signatures using its internal software.
         4. The data from the vision sensor shall be logged to an SD card located on the car.
      3. **Track Pathing**
         1. When the car sees two directional markers (left directional marker being the former, right directional marker being the latter) it will follow these actions:
            1. Signature A and Signature A causes the car to continue.
            2. Signature B and Signature B causes the car to turn around.
            3. Signature A and Signature B causes the car to turn right.
            4. Signature B and Signature A causes the car to turn left.
      4. **Basic Operation Mode**
         1. Upon power up, the car will remain in the stopped state until the user selects another operational mode: discovery, accuracy, speed, and collision avoidance.
         2. The car shall operate without any external interaction, once in another operational mode.
         3. The selection of the operational mode will be performed with button based input.
      5. **Discovery Challenge**
         1. When in this mode, no external interaction will be needed to perform any of the other requirements.
         2. This operational mode requires that the car is placed within 60.96cm of the track.
         3. Upon the initialization of discovery mode, the car will begin to search for the track.
         4. Upon locating the track, the car will
            1. Move around the track from the point of entry.
            2. Follow the instructions of the directional markers until it passes the stop line.
            3. Stop within one meter of the stop line.
         5. The car shall locate the track within one minute of initializing discovery mode.
      6. **Accuracy Challenge**
         1. When in this mode, no external interaction will be needed to perform any of the other requirements.
         2. This operational mode requires that the car is placed on the starting line of the track.
         3. Upon the initialization of accuracy mode, the car will begin to move forward around the track.
         4. The car shall follow the instructions of the directional markers until it has performed two complete laps.
         5. Upon completion of the second lap, the car shall stop within one meter of the stop line.
         6. The car shall not be required to move at any specific speed, so long it successfully performs the previously mentioned tasks for this mode.
      7. **Speed Challenge**
         1. When in this mode, no external interaction will be needed to perform any of the other requirements.
         2. This operational mode requires that the car is placed on the starting line of the track.
         3. Upon the initialization of speed mode, the car will begin to move forward around the track.
         4. The car shall follow the instructions of the directional markers until it has performed two complete laps.
         5. Upon completion of the second lap, the car shall stop within one meter of the stop line.
         6. The car shall move as fast as it is capable while successfully performing the previously mentioned tasks for this mode.
      8. **Collision Avoidance Challenge**
         1. When in this mode, no user interaction will be needed to perform any of the other requirements.
         2. This operational mode requires that the car and another car are placed on the track.
         3. Collision avoidance mode shall have two submodes: leader and follower.
         4. Upon the initialization of collision avoidance mode, the car will begin to move forward around the track.
         5. If the car is in the leader submode then the car shall:
            1. move at a pace slower than the follower submode.
         6. If the car is in the follower submode then the car shall:
            1. move at a pace quicker than the leader submode.
            2. adjust its speed, upon sensing the other car, such that it maintains a separation of no greater than 91.44cm and no less than 30.48cm from the other car.
         7. The car shall follow the instructions of the directional markers until it has performed two complete laps.
   4. **Qualitative Attributes**
      1. The car shall have a tactile interface (i.e. buttons, switches, etc.) used to change the main controller into its desired operational mode once it has been powered on.
      2. The car shall utilize a CMUcam5 Pixy for the purposes of marker recognition.
      3. The car shall utilize a Line Scan camera with a TAOS linear sensor array to recognize the track.
      4. The car shall utilize a rechargeable battery for power so that it may be used portably (i.e. without being plugged into a wall outlet).
      5. The car shall utilize a rechargeable battery for power so that it may be used portably (i.e. without being plugged into a wall outlet).
      6. The car shall use an LED to display to the user its current mode.
   5. **Quantitative Attributes**
      1. Minimum Car Speed Capability: 4.166 rotations/sec \* .2618 ft/rotation = 1.09 ft/s or at least 1 ft/s speed capabilityin speed mode.
      2. The visual sensor shall have a resolution of 640x400 pixels and shall use a hue-based color filtering algorithm to recognize track markers.
      3. The car shall utilize 1 servo to steer the car in the desired direction, and dual drive DC motors to power the wheels of the car.
      4. The car shall begin its intended operation within 5 seconds of entering the desired mode.
   6. **Options**
      1. **Headlights**
         1. The car shall have headlights on the front of the car to illuminate the track and directional markers.
         2. The lights shall turn on as the car turns on.
         3. The lights shall turn off as the car turns off.
      2. **Manual Mode**
         1. Upon the initialization of manual mode, the car shall perform the commands sent to it by the other computer via bluetooth.
         2. The valid commands shall be:
            1. Control movement speed.
            2. Control movement direction.
      3. **Website Interface**
         1. Upon the initialization of manual mode, the car shall send diagnosis information to another computer via bluetooth.
         2. The diagnosis information shall include:
            1. Movement speed of the vehicle.
            2. Movement direction of the vehicle.
         3. The other computer will be able to use a web interface to send commands to the car via bluetooth.
         4. The valid commands shall be:
            1. Change operational mode to discovery mode.
            2. Change operational mode to accuracy mode.
            3. Change operational mode to speed mode.
            4. Change operational mode to obstacle avoidance mode.
            5. Change operational mode to manual mode.
            6. Control movement speed in manual mode.
            7. Control movement direction in manual mode.
3. **Verification**

The detailed methods used for verification of the outlined requirements above are listed in the Test Plan document of the Supporting Documents section of this document. However, the generalized versions of these methods will be stated here.

The testing methods for this system are grouped based on the mode of the system under test (i.e. Accuracy Mode, Discovery Mode, etc.). Generally for each mode the correct startup must be validated, as well as user accessibility, communication to monitor, and the general functionality of each mode’s purpose. The tests themselves are mainly functional tests and do not require much interference from a software perspective; verification of the vehicle’s general functionality is the main focus and goal.

1. **Supporting Documents**
   1. **Product Concept**
      1. This Requirements Specification defines in detail all requirements of the product concept. It also expands those ideas presented in order to develop a more concrete plan for the project.
   2. **Team Contract**
      1. This document describes the rules and constraints under which the team shall operate.
   3. **Test Plan**
      1. This document describes how each part of the specification shall be tested and verified.
   4. **List of Deliverables**
      1. This document describes everything that shall be given to the customer.
2. **References**
   1. "Code of Ethics | National Society of Professional Engineers", *Nspe.org*, 2017. [Online]. Available: https://www.nspe.org/resources/ethics/code-ethics.
   2. "IEEE IEEE Code of Ethics", *Ieee.org*, 2017. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html.
   3. R. Ford and C. Coulston, *Design for Electrical and Computer Engineers*. McGraw-Hill, 2005.
   4. “Core System Requirements Specification (SyRS)”, 2011. RITA Intelligent Transportation Systems Joint Program Office. [Online]
   5. IEEE Recommended Practice for Software Requirements Specifications," in *IEEE Std 830-1998* , vol., no., pp.1-40, Oct. 20 1998 doi: 10.1109/IEEESTD.1998.88286
   6. IEEE Guide for Developing System Requirements Specifications," in *IEEE Std 1233, 1998 Edition* , vol., no., pp.1-36, Dec. 29 1998 doi: 10.1109/IEEESTD.1998.88826